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1967-4

C. G. Ryan

Magnetic Film Memory Evaporation System

6 January 1967

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Lexington, Massachusetts



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MAGNETIC FILM MEMORY EVAPORATION SYSTEM

C. G. RYAN

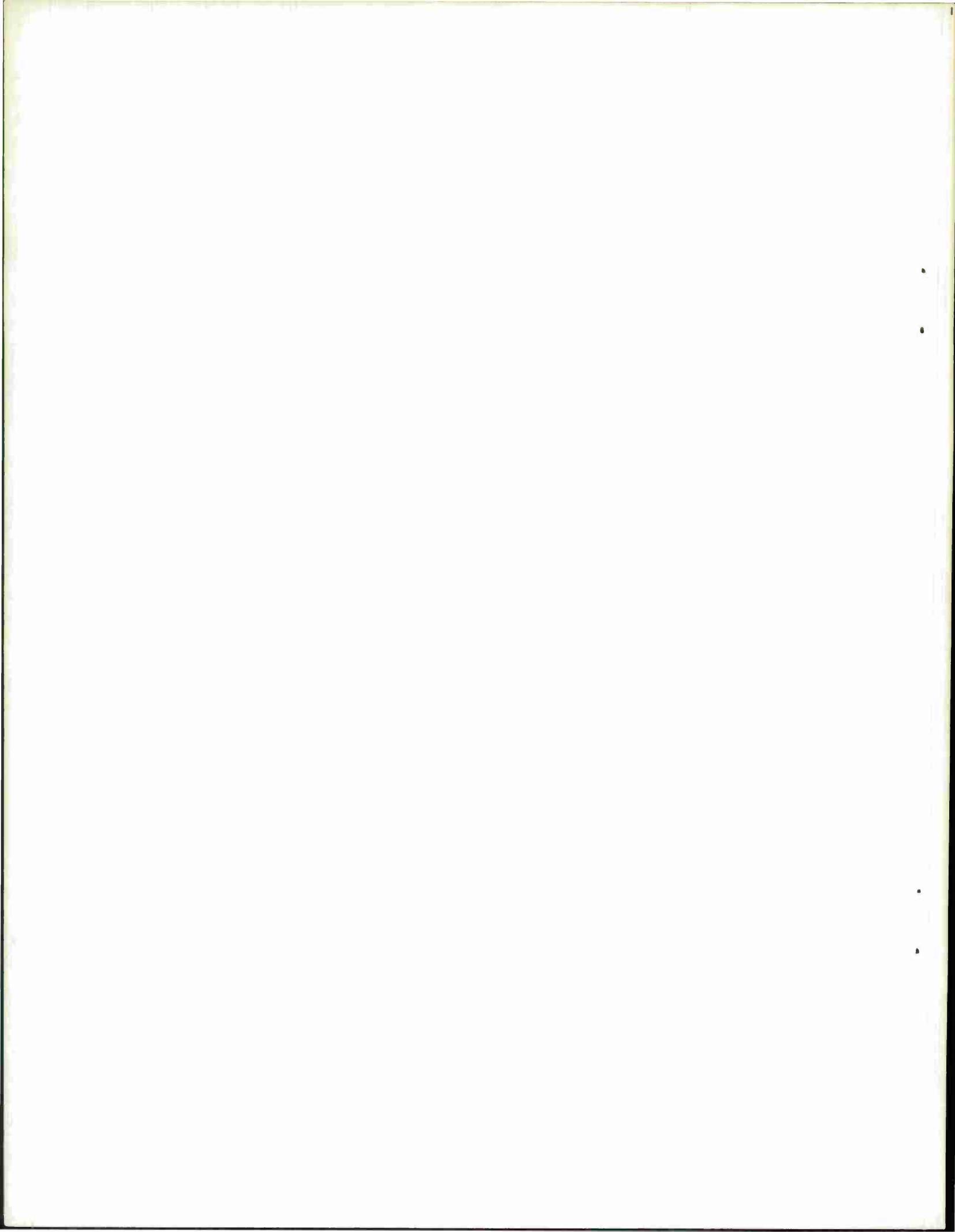
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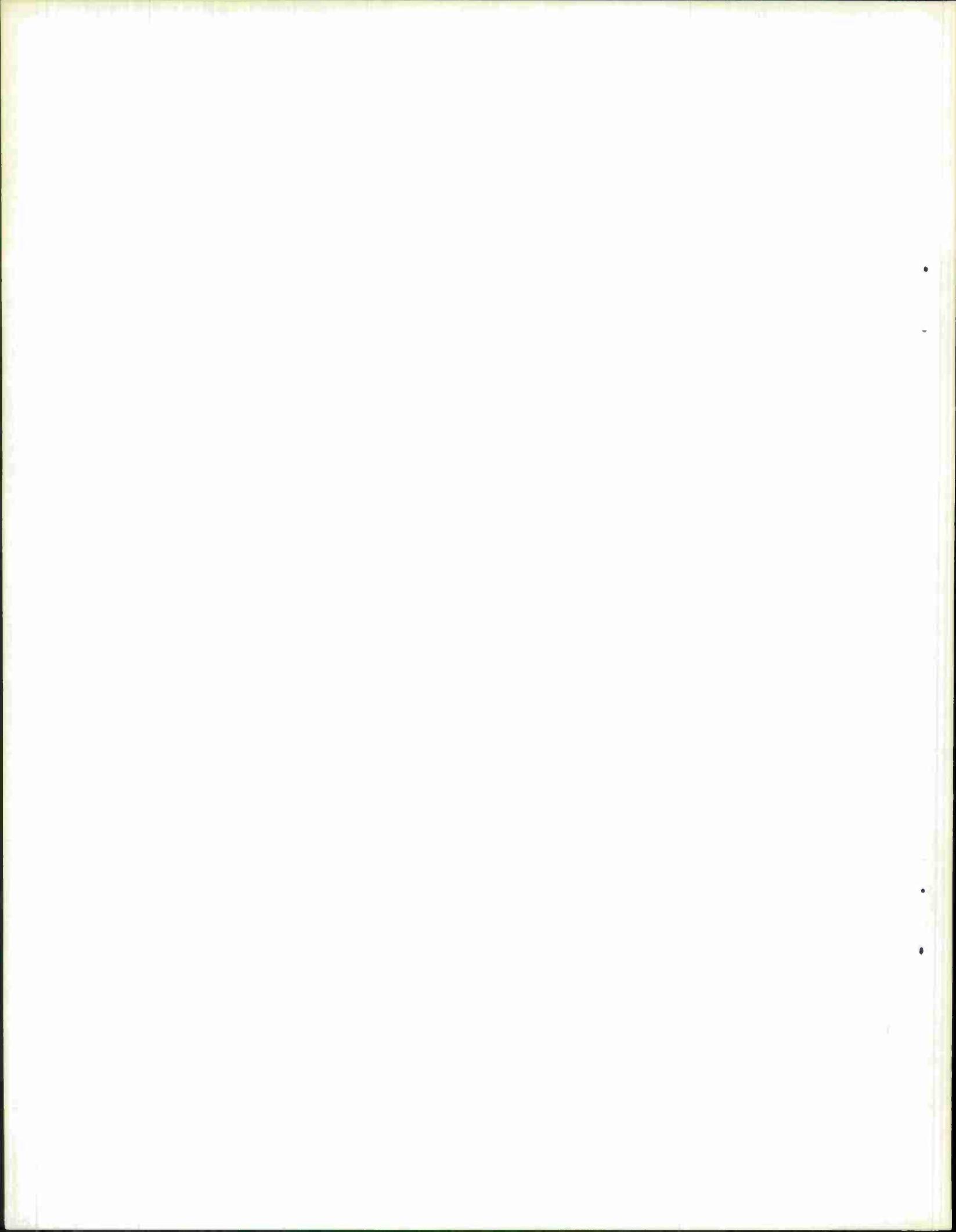
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ABSTRACT

This system facilitates the deposition of large area magnetic film memories and the observation of wall coercive force during an annealing cycle. It provides for sixteen substrates 1.6 inches wide by up to thirty inches in length to be sequentially coated. Three induction heated sources are employed containing up to one pound of melt in each crucible plus additional resistance heated sources for the evaporation of a chromium under-layer which enhances adhesion of the magnetic film to the substrates.

Accepted for the Air Force
Franklin C. Hudson
Chief, Lincoln Laboratory Office



INTRODUCTION

With rising element density in microelectronics, interconnections contribute an increasingly larger part of the total cost of any system. In the case of a large capacity magnetic film etched line memory, this consideration dictates that the memory substrate be made as long as practical. For the one-million bit prototype memory described more completely elsewhere,⁽¹⁾ glass substrates approximately twelve inches long are used (see Figure 1). This report will concern itself with a description of the vacuum system, remote controlled substrate changer and associated apparatus employed for the production of these memory elements. Operating procedures and measuring techniques will also be outlined.

VACUUM CHAMBER AND PUMPS*

The chamber is 4' diameter by 4' long, 1/4" wall series 304ELC stainless steel annealed subsequent to fabrication to reduce magnetization. Eight flanged ports provide entry and three smaller ports are used for viewing. All internal surfaces received a #4 polish at Consolidated Vacuum Corporation. (See Figure 2.)

* Supplied by Consolidated Vacuum Corp., Rochester, New York.

The pumping system is comprised of the following components:

- (1) Consolidated Vacuum Corp (CVC) PMC-18,000 diffusion pump.
- (1) Kinney KDH-250 mechanical backing and roughing pump.
- (1) Welch 1403B holding pump.
- (1) 20" pneumatic high vacuum valve.
- (1) 6" pneumatic roughing valve.
- (1) 6" pneumatic forepressure valve.
- (1) CVC Type BC003 automatic liquid nitrogen filler assembly.

A control cabinet containing pressure gauges, valve actuating and liquid N₂ controls switches were also supplied by CVC.

MELT SOURCES

A model T-20-3-KC-A-H Lepel High Frequency Laboratory's induction heater is used for heating the melts. The input power requirement for this three-phase generator is 230 volts, 110 amps, with a nominal output power of 20 kw. Three remotely switched outputs are provided, one for each load coil. These coils are four turns of 1/4" diameter copper tubing, wound to fit two nested 60°, 3" diameter alundum cone crucibles (Norton RA-84).

The cooling water system has been modified to allow circulation to the three coils simultaneously, thus preventing overheating of the closely adjacent coils. R. F. power is brought into the vacuum system via o-ring sealed teflon feed-throughs located in a flange beneath the chamber.

Three resistance-heated coils mounted on top of the shutter assembly (Figure 3) evaporate a chromium film which improves the bond between subsequent layers and the substrate. These coils are 60° cones with a 1/2" maximum diameter, wound from 0.030" diameter tungsten wire and coated with alundum to prevent the metal from shorting the turns.*

SUBSTRATE CHANGER

This fixture (see Figure 4) consists of two circular end plates, which support sixteen rails between them. Each substrate is sandwiched between two frames which slide into matching slots running the length of the rails. This serves to positively locate the substrates when the changer is rotated. To simplify cleaning, thin stainless covers are placed over the rails to shield them from the evaporant. These covers may be easily removed for etching away the accumulated coating. Aluminum dust shields wedged between the rail covers serve to protect the substrates (see Figure 5). Prior to deposition, as the changer is rotated, a stationary hook engages a loop in

* Manufactured by C&M, Inc., Bloomfield, New Jersey (Part #R-307C).

each cover, pulling it away from the substrate.

Changer indexing is accomplished by a 1/50 hp, 60 rpm motor mounted externally on the top of the chamber. The drive is via a solenoid actuated single revolution clutch, a universal joint, and an o-ring type vacuum seal. A 2:1 bevel gear set and an 8:1 spur gear set in the chamber give the 16:1 reduction necessary for indexing the changer by one substrate for each motor shaft revolution.

The changer is mounted on a dolly, which also supports the shutter, chimney, thickness monitor and hysteresigraph coils. Two sets of matching tracks, one in the chamber and the other on a hydraulic lift truck, allow the entire fixture to be rolled out of the chamber for maintenance, loading and unloading.

The shutter assembly, located on the lower portion of the dolly (see Figure 3), consists of three hinged shutter plates which are approximately 2" above the melts when closed. A drive shaft opens and closes the shutters with a push-pull motion, and selects the shutter to be actuated by rotation in 90° increments. The shutter drive is pneumatically operated from outside the chamber via a MRC V-4-110 rotary, push-pull vacuum seal.

A sheet-metal chimney is inserted in the dolly between the shutters and the substrate changer. Its function is to confine the metal deposit to simplify cleaning of the system. The chimney and all other parts subjected to high temperatures are fabricated of Inconel X, a non-magnetic material

having a relatively low coefficient of expansion and good high-temperature structural properties.

SUBSTRATE HEATER AND TEMPERATURE MONITORING

The substrate heater is wound along the changer axis to achieve symmetrical heating of the substrates. It is a 3 strand, 0.040" tungsten wire coil, 5/8" I.D., 30" long with 5 turns per inch. One quarter O.D. tantalum rod, insulated by a fused zirconia sleeve, supports the filament, and a quartz tube around the heater prevents contamination of the substrates by WO_3 evaporating from the filament.

The substrate temperature ($200^{\circ} - 400^{\circ}\text{C}$) is monitored by a surface mounted platinum resistance thermometer attached to a dummy substrate. Electrical contact is made through a commutator to a bridge circuit, and temperature readings are registered on a digital voltmeter.

DEPOSITION THICKNESS MONITOR

The thickness of the metal layers is monitored throughout the deposition with quartz crystal monitor, (Sloan Instruments DTM-2), having a digital read-out. (General Radio Model 1150-B.)

This monitor uses a crystal changer which is a solenoid actuated mechanical injector, with a magazine holding thirty crystals. The unit is maintained

at a constant temperature by circulating water through a compartment directly behind the active crystal. In addition to preventing overheating of the unit, this arrangement reduces spontaneous peeling of the deposit from the crystal.

FIELD COILS

Two 6' diameter Helmholtz coils each with 250 turns of 10 AWG copper wire with class H insulation surround the chamber and produce 38 oersteds D.C. at 12 amps for orientation of the magnetic anisotropy.

WALL COERCIVE FORCE MONITOR

Drive and sense coils of a hysteresigraph⁽²⁾ are mounted inside the vacuum chamber in order to monitor the wall coercive force during the annealing cycle.

The 5" x 13" x 5" rectangular drive coil (see Figure 6) with 220 turns of teflon insulated, number 18 AWG copper wire is wound on a supramica form. This coil is driven at 120 CPS by an audio oscillator driving a 60 watt power amplifier to supply peak fields of 20 oersteds, which switch the film's magnetization by wall motion.

A 10,000 turn sense coil (see Figure 6), positioned within the drive coil, detects the changing flux normal to the plane of the switching film. These signals are amplified by a Tektronix Type 122 low-level

preamplifier and displayed as the (y) input to an oscilloscope whose x input is proportional to the driving field.

OPERATION

Substrates of 10.76" x 1.6" x 1/4" optically polished plate glass are ultrasonically cleaned in tanks mounted in a clean bench. These are loaded into sleds along with small test pieces for checking copper thickness, adhesion and magnetoelastic sensitivity, and placed in the substrate changer. The entire operation is carried out in a Class 10,000 clean room.

After the changer is rolled into the chamber and the necessary electrical connections are made, the chamber is evacuated to 5×10^{-5} torr and the substrate heater is turned on. With a maximum power input of 4.4 kw, at least 90 minutes are necessary to reach and stabilize substrate temperatures.

A typical large capacity memory run consists of the following steps:

- (1) Heat substrates to 320° and stabilize.
- (2) Evaporate 100 - 300 Å of chromium on each substrate by stepping the changer, since the chromium sources are not shuttered. Total evaporation time is approximately 15 minutes.

- (3) Evaporate 1500 \AA of 10% Co, 72% Ni, 18% Fe alloy with 99.9% purity constituent metals on each substrate in an orienting field. The total time for melting and evaporating is approximately 25 minutes, with a rate of about 3000 \AA per minute.
- (4) Cool substrates to 150 $^{\circ}\text{C}$ (1-1/2 hours required for cool down).
- (5) Evaporate 40,000 \AA of 99.9% pure copper (melt weight 1 lb.) with orienting field on. The maximum evaporation rate is 4,000 $\text{\AA}/\text{minute}$ to minimizing spattering of copper onto the substrates, and seven substrates per melt may be evaporated at this thickness. Total evaporation time for twelve substrates is three hours.
- (6) Increase substrate temperature to 300 $^{\circ}\text{C}$ for diffusion of copper into the magnetic alloy to increase adhesion and to raise wall coercive force (H_c). H_c is monitored with heater and field coils temporarily shut off. An H_c of 10 oersteds is desired at room temperature and substrates are further annealed to as high as 400 $^{\circ}\text{C}$ and intermittently monitored. Figure 7 shows the effect of copper diffusion in increasing the coercive force during an annealing cycle. After diffusion has taken place H_c is seen to be a reversible function of temperature if the original annealing temperature is not exceeded, Figure 8. The effect of copper diffusion on the magnetic properties of films is described elsewhere.^{3,4}

ACKNOWLEDGEMENT

The sophistication of design of the original concept was largely the work of Mr. A. M. Sanderson and Mr. C. A. Boyden of the Design Engineering Group. The entire project was directed and supervised by T. S. Crowther and T. O. Herndon.

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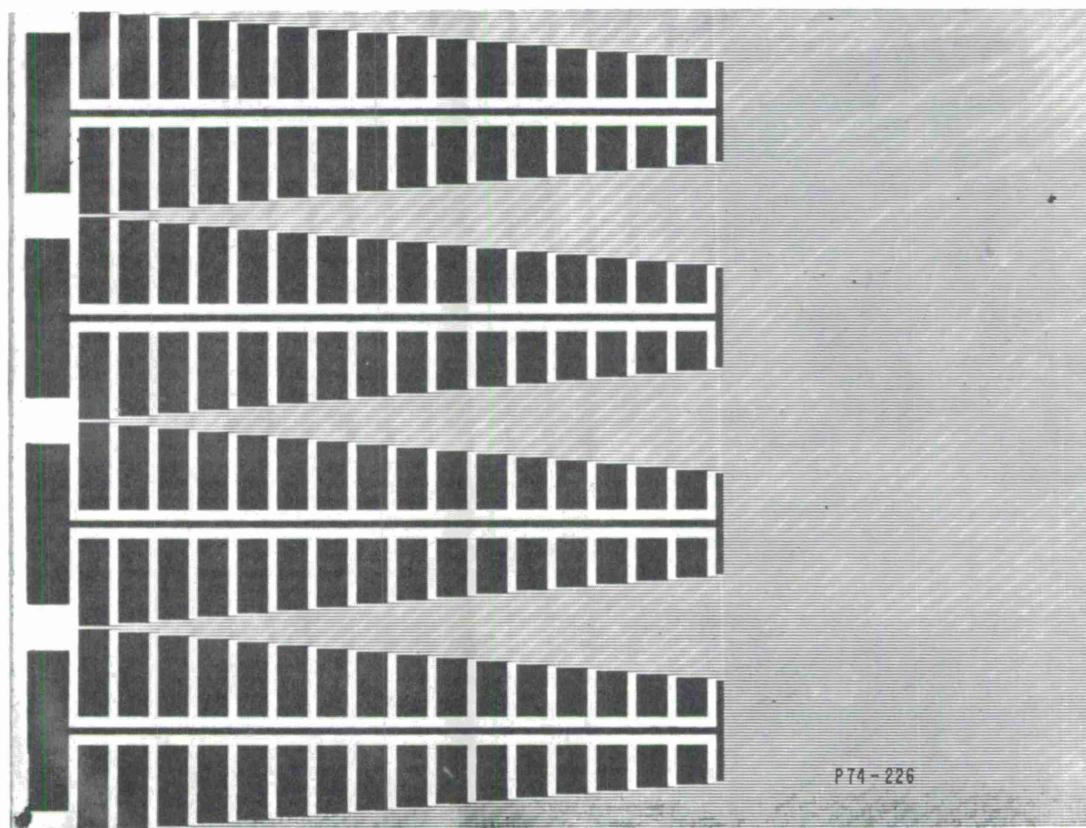


Figure 1 Etched substrate

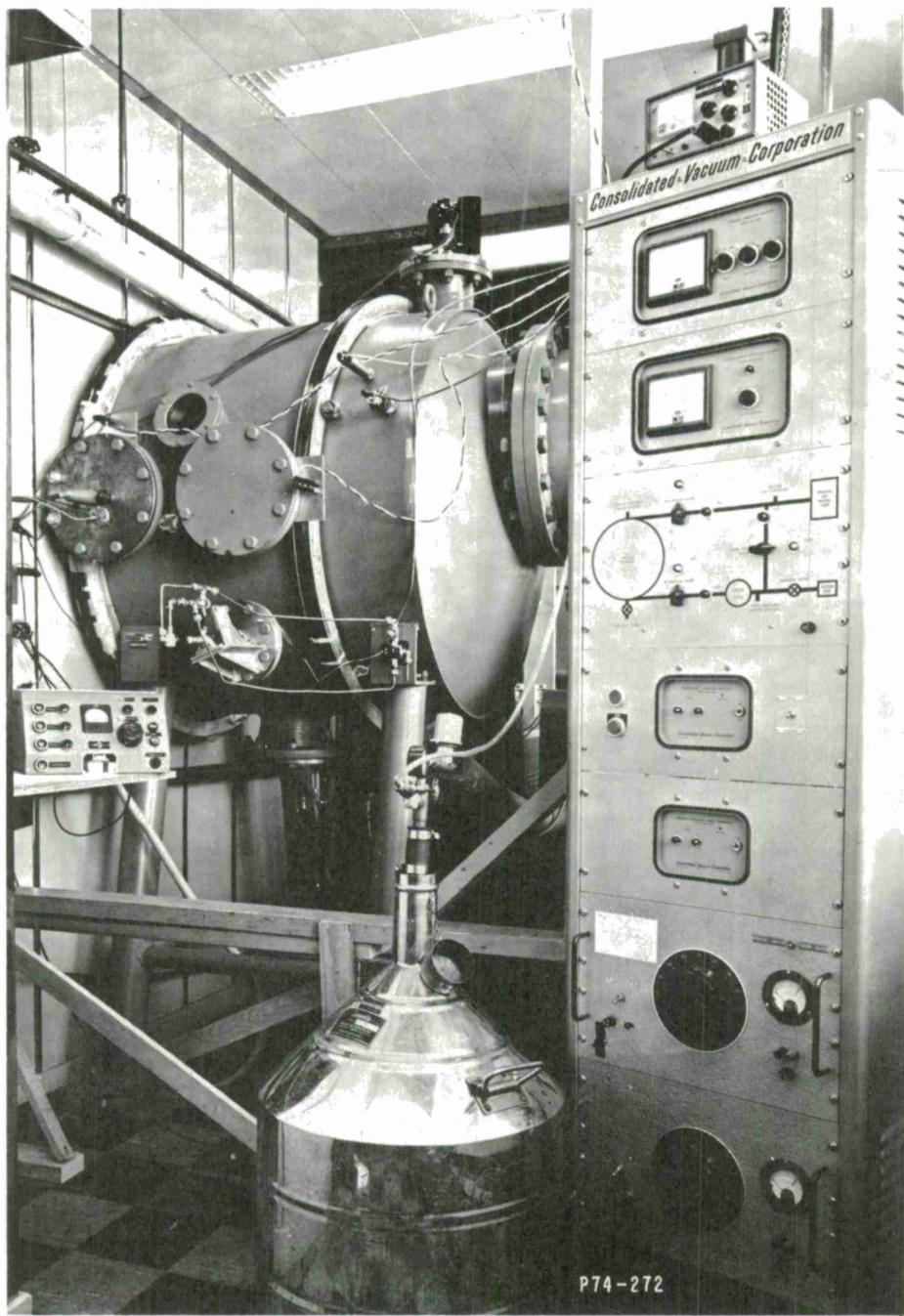


Figure 2 Photo vacuum chamber external

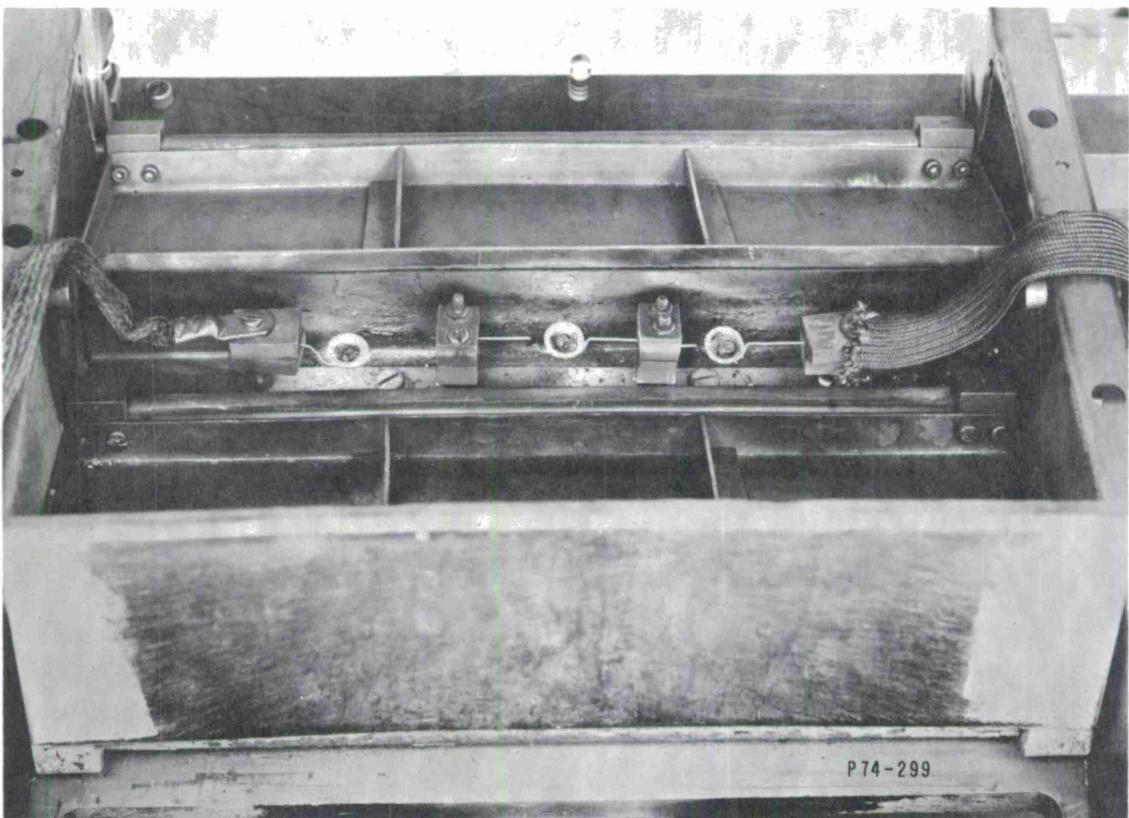


Figure 3 Photo shutters and chromium sources

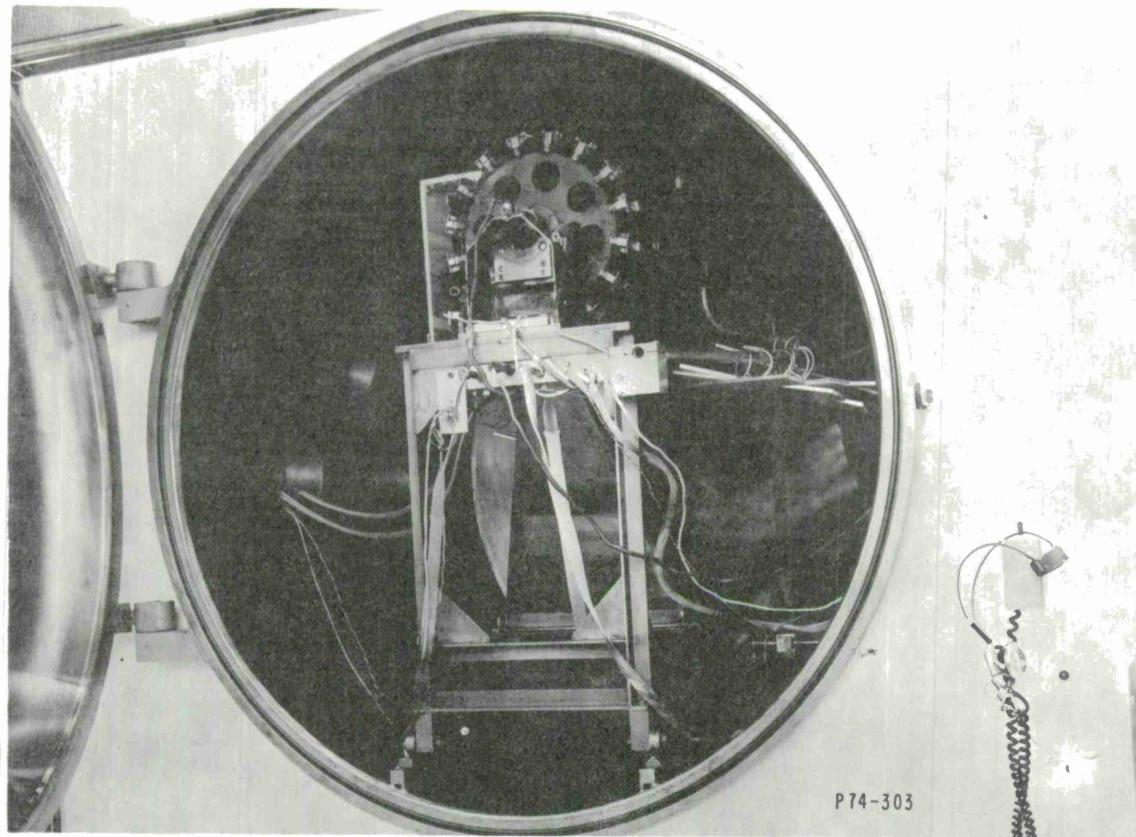


Figure 4 Photo drum substrate changer

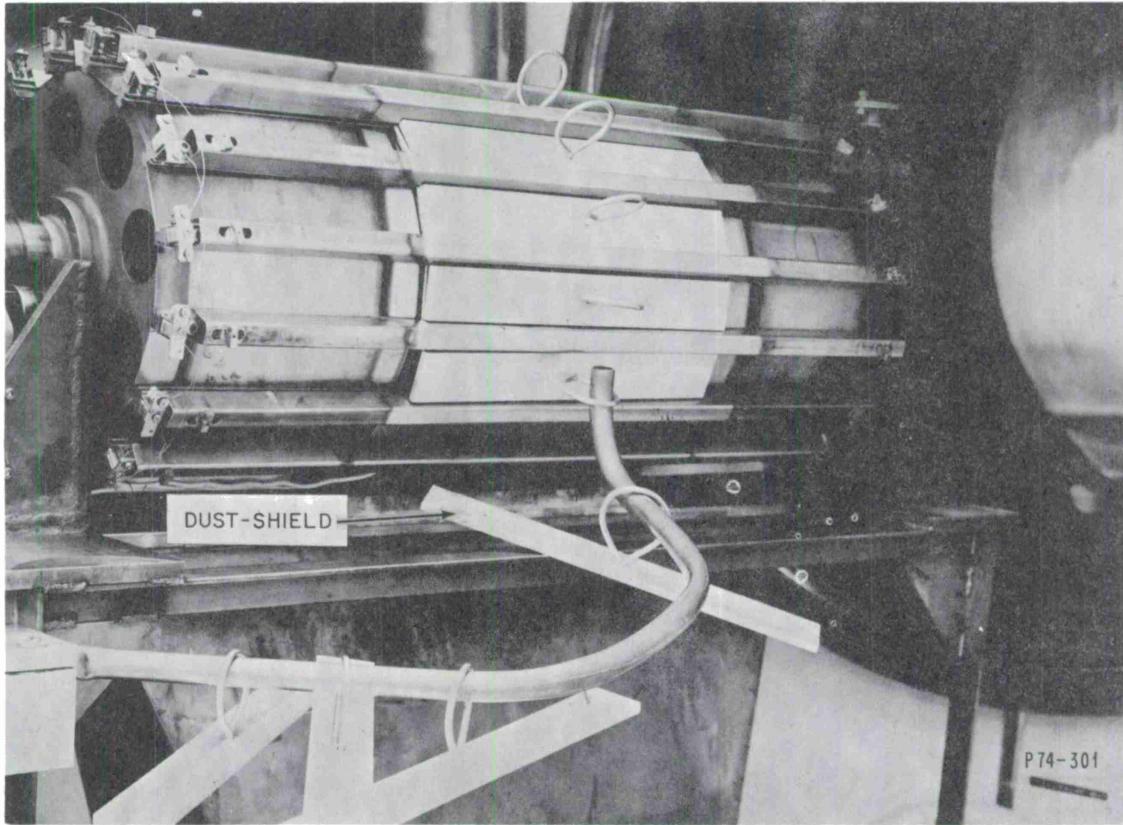


Figure 5 Photo removal of dust covers

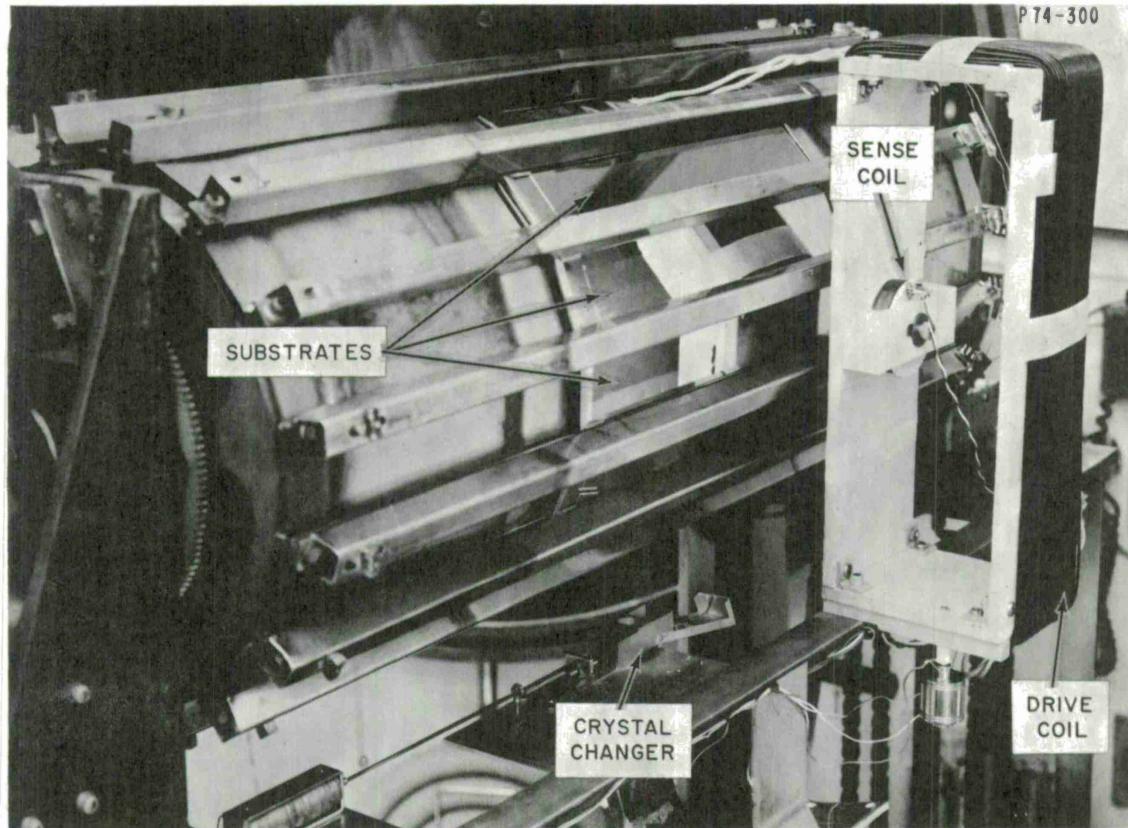


Figure 6 Photo crystal changer and hysteresigraph drive and sense coils

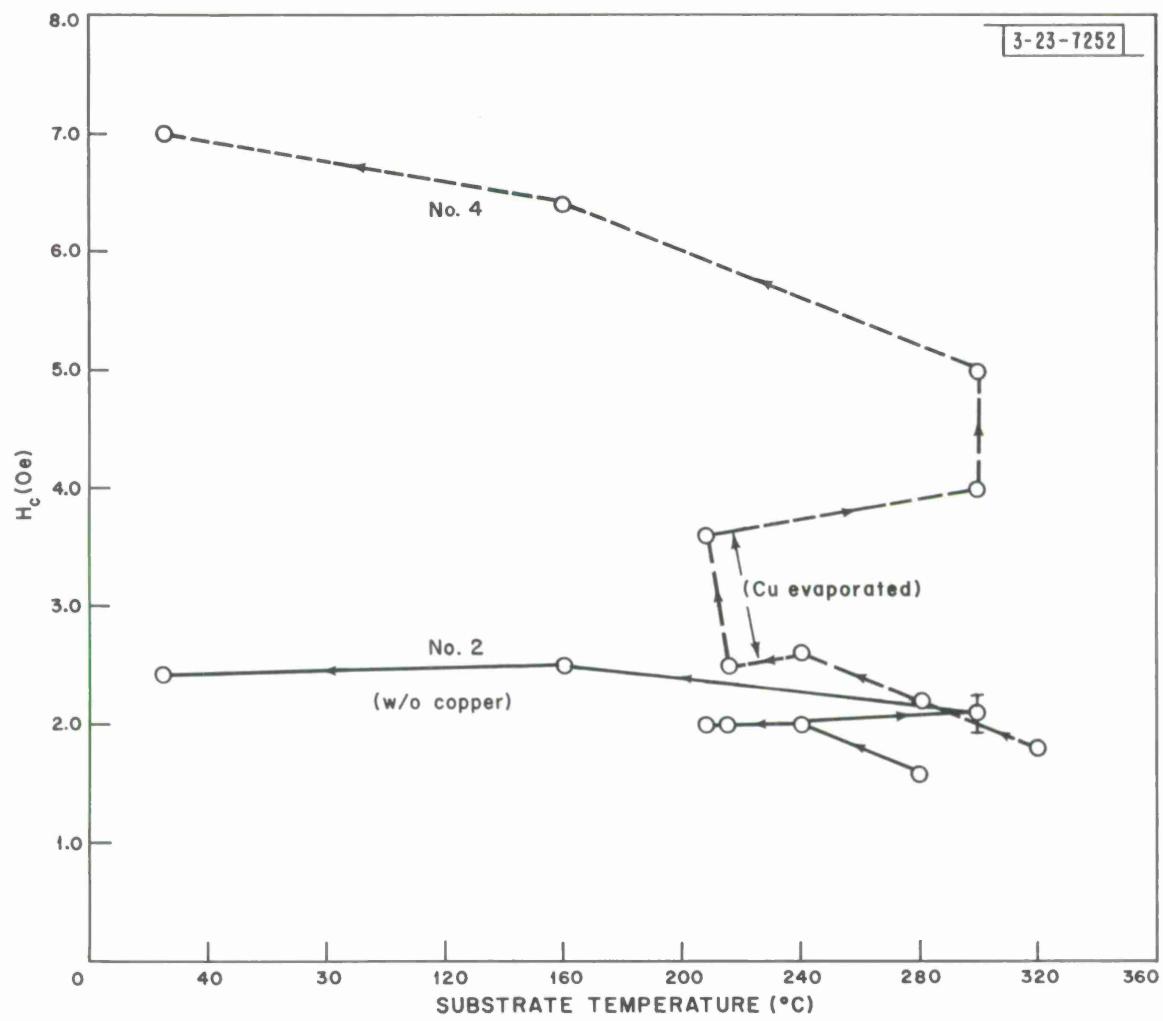


Figure 7 Curve — H_c versus substrate temperature with and without Cu overlays

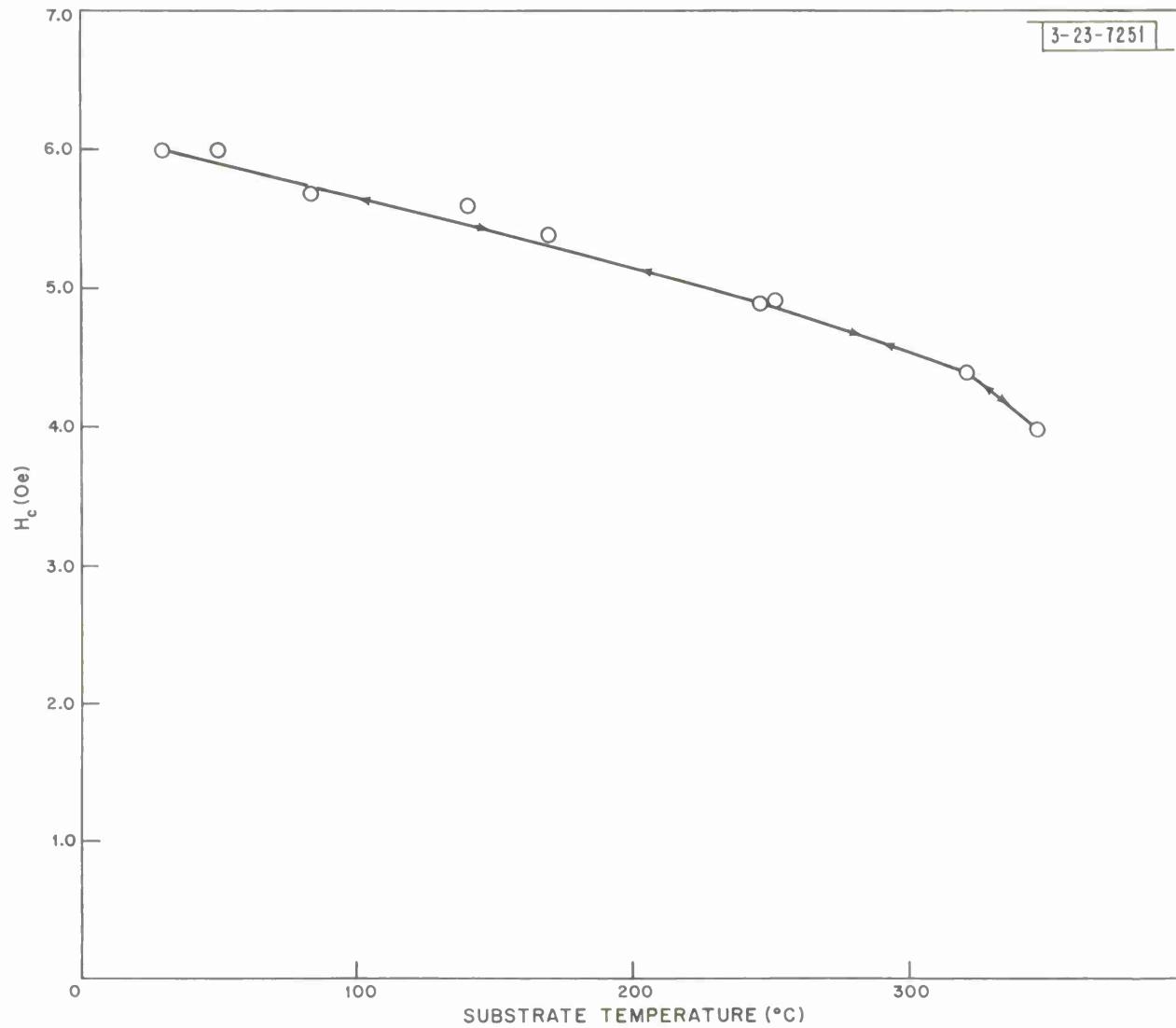


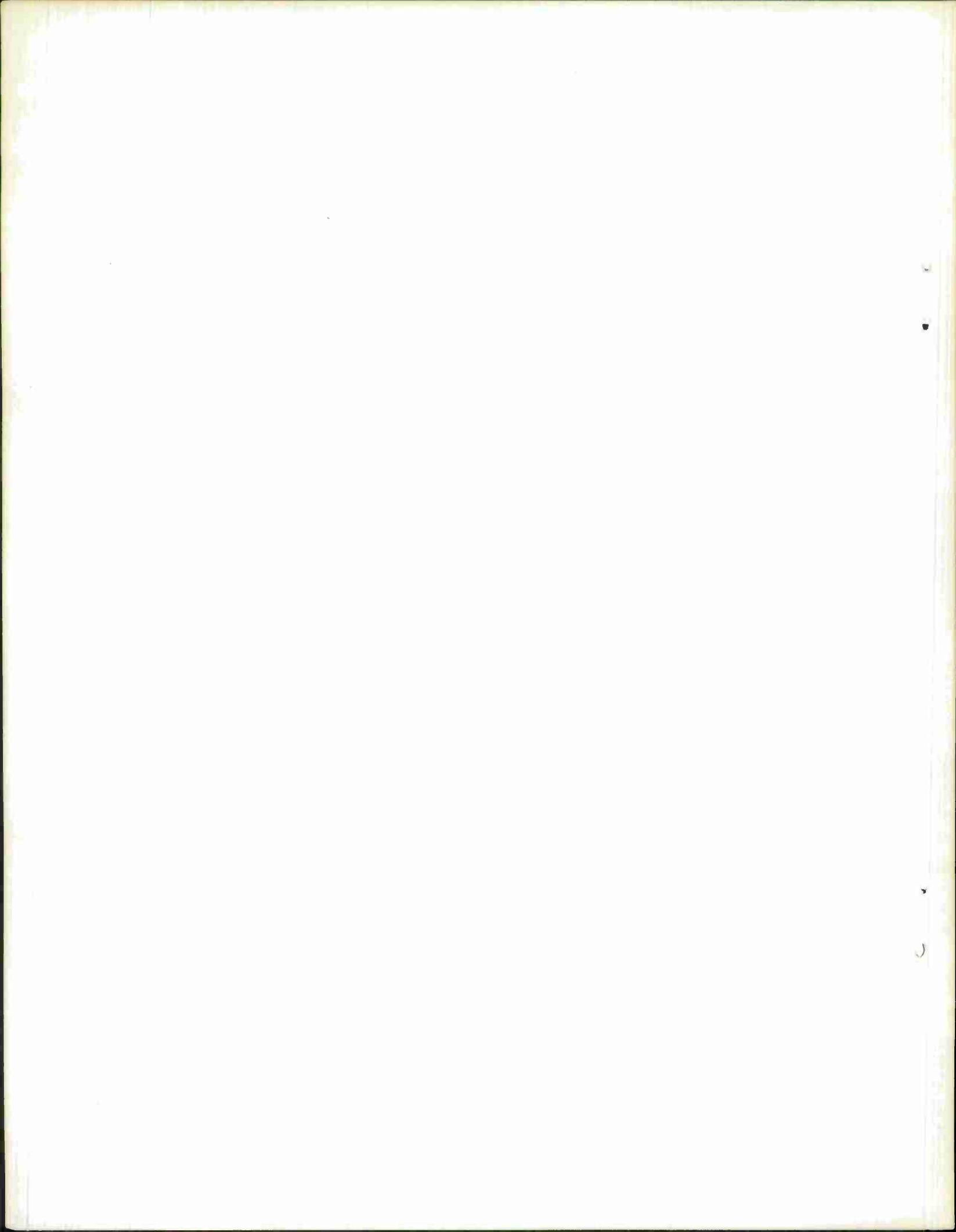
Figure 8 Curve — H_C versus substrate temperature

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